The power received by the antenna-coupled detector is determined from the collection area and the laser beam irradiance. Based on the collected power, we estimate a room-temperature noise-equivalent power (NEP) of < $7 nW/Hz^{1/2}$. This NEP is measured at an operating bias voltage of 100mV and at high frequency, where the Johnson noise dominates the $1/f$ noise. Optimisation of the resonance frequency of the antenna is expected to decrease this NEP.

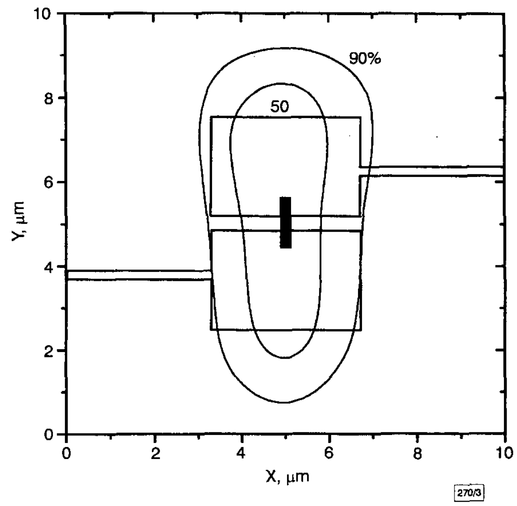


**Fig. 3** *Geometry of antenna-coupled infrared detector*

Contours of areas enclosing 50 and 90% of volume of spatial response are shown

*Conclusions:* The first microstrip antenna structure that detects thermal infrared radiation has been reported. It has an excellent polarisation ratio (> 20:1), is extremely fast for a bolometer detector (150 ns), and has a collection area of $24 \mu m^2$. The NEP is of the order of $7 nW/Hz^{1/2}$.

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## Adaptive predistorter for power amplifier based on real-time estimation of envelope transfer characteristics

Jae-Hee Han, Tasik Chung and Sangwook Nam

A new adaptation technique for digital predistortion is presented. The proposed method employs the real-time input and output signals of a high power amplifier (HPA) to estimate the complex envelope transfer characteristics. Therefore, a look-up table update can be performed without interrupting the normal transmission of messages through an HPA.

*Introduction:* Spectral regrowth (SR) or intermodulation distortion (IMD) generated by a nonlinear high power amplifier (HPA) causes interferences in adjacent communication channels. Hence, many linearisation techniques for HPAs such as feedforward, feedback and predistortion have been developed to combat these problems. These linearisers should be adaptive to the variations in the characteristics of the HPA. The digital predistorter is one of the most promising means for carrying out linearisation because of its high levels of performance and adaptability [1 – 4].

In a digital predistorter, the input signals are distorted according to a look-up table (LUT) which contains the inverse characteristics of the HPA. To maintain the suppressed SR or IMD at a desired level, the LUT should be updated with the changes in the characteristics of the HPA [2]. Therefore, fast and precise adaptation is an important issue in digital predistortion because it determines the system performance.

In this Letter, a new adaptation technique for the digital predistorter is proposed. The LUT is updated by the real-time estimation of the complex envelope transfer characteristics of the HPA. The estimation is carried out using the real signals transmitted through the HPA. Moreover, the proposed estimation algorithm does not depend on the modulation format.

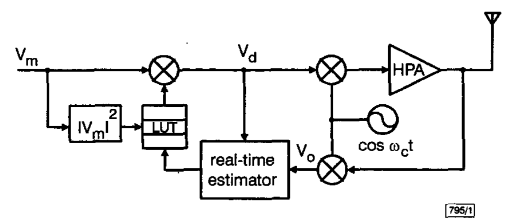


**Fig. 1** *Simplified block diagram of proposed digital predistorter*

*Description of system:* A simplified block diagram of the proposed system is shown in Fig. 1. This system is composed of the predistorter and the estimator. In the predistortion part, the desired signal $V_m$ is distorted according to a one-dimensional LUT [2] and applied to the input of the HPA. In the estimation part, the input and output complex envelopes of the HPA, $V_d$ and $V_o$, are sampled for the real-time estimation of the complex envelope transfer function. Its inverse function is then obtained to be used to update the LUT. The flowchart for the entire estimation and update procedure is shown in Fig. 2.

*Estimation of characteristics*: Using the notation in Fig. 1, the relationship between the input and output complex envelope of the HPA can be expressed by [1]

$$V_o = \sum_{k=0}^{N} \beta_{k+1} r_d^{2k} V_d \qquad (1)$$

where $r_d = |V_d| = \sqrt{[I_d^2 + Q_d^2]}$ and the complex coefficients $\beta_k = a_k + jb_k$ account for the AM/AM and AM/PM distortions of the HPA. Taking the real part of eqn. 1, the output in-phase component becomes

$$I_o = \phi^T \cdot \theta \tag{2}$$

where $\phi = [I_d, Q_d, r_d^2 I_d, r_d^2 Q_d, ..., r_d^{2N} I_d, r_d^{2N} Q_d]^T$ is the input data vector and $\theta = [a_1, -b_1, a_3, -b_3, ..., a_{2N+1}, -b_{2N+1}]^T$ is the HPA model coefficient vector.

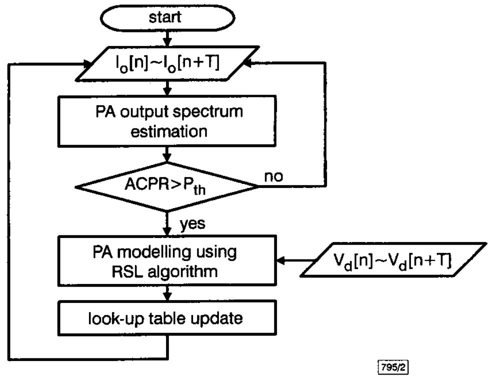


**Fig. 2** *Flowchart of estimation and update process*

By applying a recursive least squares (RLS) algorithm to estimate the $\beta_k$s in eqn. 2, the $n$th time update equations can be written as [5]

$$\hat{\theta}[n] = \hat{\theta}[n-1] + \mathbf{L}_n\left(I_o[n] - \hat{\theta}^T[n-1]\phi[n]\right)$$

$$\mathbf{L}_n = \frac{\mathbf{P}_{n-1}\phi[n]}{1 + \phi^T[n]\mathbf{P}_{n-1}\phi[n]}$$

$$\mathbf{P}_n = \mathbf{P}_{n-1} - \frac{\mathbf{P}_{n-1}\phi[n]\phi^T[n]\mathbf{P}_{n-1}}{1 + \phi^T[n]\mathbf{P}_{n-1}\phi[n]} \tag{3}$$

where $I_o[n]$ is the sampled in-phase component from the output of the HPA at time $n$, $\phi[n]$ is the input data vector at time $n$ and $\hat{\theta}[n]$ is the $n$th time estimated coefficient vector. The initial values for eqn. 3 are taken as

$$\mathbf{P}_0 = \delta^{-1}\mathbf{I}$$

$$\hat{\theta}[0] = \mathbf{0} \tag{4}$$

where $\delta$ is a positive number, $\mathbf{I}$ is the $2(N+1) \times 2(N+1)$ identity matrix and $\mathbf{0}$ is the $2(N+1) \times 1$ zero vector.

No restriction is placed on the input data vector in deriving eqn. 3. Therefore, any kind of complex envelope input can be used for the proposed estimation algorithm. Moreover, the output data can be provided by a direct downconversion instead of quadrature demodulation, because only the in-phase component of the output signal is used in eqn. 3 to estimate the coefficient vector $\hat{\theta}[n]$. While the estimation is performed with the RLS algorithm in the work described in this Letter, other adaptive algorithms can be used to estimate the model coefficients of the HPA.

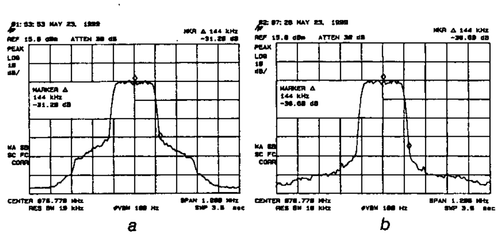


**Fig. 3** *Measured output spectra of HPA*

*a* Nonlinear output spectrum
*b* Linearised output spectrum

*LUT update*: The inverse characteristics required for the LUT update can be obtained by applying a simple adaptation method such as the least squares algorithm to the estimated transfer function. Usually, when the LUT is updated a training interval is established in which the HPA does not transmit messages. As stated previously, this undesired interruption can be avoided by using the proposed adaptation method, because the changes in the table contents are based on the estimated transfer function.

*Implementation and results:* The proposed lineariser was implemented with two TMS320C44 processors from Texas Instruments Inc., one for predistortion and the other for estimation and update. First, the envelope transfer characteristics of the HPA are estimated by applying 357.142kHz pulse-shaped random quadrature phase shift keying (QPSK) signals to the HPA. The lineariser performance is tested using the proposed adaptation technique. The nonlinear and linearised spectra are shown in Fig. 3. We obtained ~10 dB of adjacent channel power ratio (ACPR) improvement at the centre of the adjacent channel.

*Conclusion:* A new adaptation algorithm for the digital predistorter has been presented. The proposed technique employs the real-time transmitted signals through the HPA to perform table updates, hence the signal transmission of the HPA is not affected during the adaptation process. The experimental results presented validate the technique of digital predistortion based on the real-time estimation of the envelope transfer characteristics of the HPA.


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# Analytic technique for accelerating simulation of generic network traffic

J. Schormans, E. Liu, L. Cuthbert and G. Stoneley

The authors propose a methodology for the acceleration of simulation studies in cell or cell based communication networks by the use of a hybrid analytical/simulation combination. This relies on a mathematical technique for the separation of foreground traffic from background traffic and focuses on cell by cell simulation, complementing recently completed work on accelerated methods for rate based simulations.

*Introduction:* Many complex communication systems providing support for multimedia are still at the proposal/design evaluation stage. Most of these systems are to be based on forms of cell switching, and yet the precise performance of the cell buffering will not necessarily be of prime interest. It is the nature of service specific studies that they require a network (and other, 'background', traffic) to be present in the study, while measurements on the background traffic itself are irrelevant. The work presented in this Letter is generic and applies equally to cell-switched ATM networks and packet-routed IP networks; however we use 'cell' throughout the rest of the Letter.

We propose a technique for the acceleration of cell based (rather than rate based) simulation studies of communication net-